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TITLE: **APPARATUS AND METHOD FOR MANUFACTURING METAL MOLD USING SEMISOLID RAPID TOOLING**

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APPARATUS AND METHOD FOR MANUFACTURING METAL MOLD USING SEMISOLID RAPID TOOLING

Technical Field

This invention relates to an apparatus and a method for producing metallic molds of various kinds used indispensably in manufacturing various kinds of industrial products and their components. More specifically, this invention relates to an apparatus and a method for producing metallic molds using a semisolid rapid tooling (SRT).

Background Art

Recently, the desire for the product of consumers has become diversified together with the development of industry. According to this trend, the life cycle of the product is shortened and the shape of the product has complicated curved surfaces in many circumstances to match tastes of the consumers. Therefore, the mold for manufacturing such a product also has a complicated shape.

The product having complicated and various shape, usually, is manufactured by a mold such as an injection mold, a blowing mold, a die casting mold, a press mold, etc. and such a mold is produced by a machine cutting method and an electric discharge machining method, etc.

However, a mold producing method such as a machine cutting method, and an electric discharge machine method, etc. needs a method for modeling the shape of the mold

efficiently in order to machining the mold having a complicated shape smoothly and precisely. In addition, for example, at the time of machining the mold, the design of a tool path and machining conditions depending on a mold machining have to be set in ahead from a modeling information described in detail above, so that the problem such as an interference phenomenon between tools does not occur.

Accordingly, when considering a trend in which the shape of the product is getting complicated and diversified and the life cycle of the products is getting shortened, it is hard to satisfy the consumers because the time required in producing such a complicated mold necessary for the fabrication of the complicated product is lengthened, thereby making it impossible to send out the product in a time the consumers want, and the cost competitiveness of the product is getting worse because the cost required in producing the complicated mold is also high.

The inventors disclosed, in the specification of Korean Patent No. 268604, "a method and an apparatus for producing a mold using a semisolid metal molding" which may make the production of a mold more rapid and more inexpensive, considering the above problems. According to the disclosed method and apparatus, a metal powder is heated to a semisolid state where a solid phase and a liquid phase are mixed. Then, this semisolid material is filled under pressure into a molding flask and is cooled. Thus, a mold is produced. According to such a method and an apparatus, it is not necessary to consider the matters such as the design of

a tool path and machining conditions based on the mold machining at the time of producing the mold. Therefore, the time and cost required in the development and the production of the mold can be greatly decreased.

However, in the case of the Korean patent No. 268604, the metal powder being used as mold material are very expensive and are hard to obtain. It is also not easy to mix the metal powder in a proper ratio. In addition, when the metal powder is used, a graphite die set filled with the metal powder indispensably has a great volume and the total volume of the apparatus thus increases. In addition, when the metal powder is pressed in the semisolid state from both sides of up and down, it is difficult to press it in a proper pressure. It is also a hard and time-consuming work to change a mold flask when the mold flask is installed in the interior of the graphite die set.

This applicant disclosed, in the specification of Korean Patent No. 320494 "Apparatus and method for producing a mold using a semisolid metal molding method" which solved drawbacks described in the specification of Korean Patent No. 26804. According to Korean Patent No. 320494, die steel in the form of a bar is heated into a semisolid state and the semisolid steel is then filled under pressure into a mold flask and cooled. Thus a mold is produced. According to such a method and an apparatus, since a bar die steel relatively inexpensive and easy to supply and demand is used as die steel material, the cost is basically reduced, together with the miniaturization of an apparatus and easy

process control.

However, there are still the rooms to improve in the invention described in the specification of the above patent No. 320494. Firstly, it is not technically easy to make both a surface region and a central region of large sized die steel into homogeneous semisolid state. There is inevitably a temperature difference between the surface region of and the central region of the large sized die steel heated. When such a temperature difference is large, homogeneous semisolid state cannot be generally obtained. Accordingly, there is a limit in employing die steel having a large temperature difference of the surface region and the central region thereof during heating. Eventually, this limits the size of a mold which can be produced. In addition, the most important technical matter to be considered in the process of producing a mold that uses semisolid state die steel is to control a temperature of an upper region of die steel being heated. The upper region of die steel is a region which contacts the mold flask first of all when the heated die steel is fed into a mold space of the mold flask and thus has a decisive effect on the quality of a mold being produced. However, the invention described in the specification of Korean Patent No. 320494 did not solve the problem of the loss of heat produced in the upper region of die steel heated by the radiation and the convection, Therefore, the temperature of the upper region of die steel thus becomes relatively lower than those of other regions thereof.

Disclosure of the Invention

This invention is contrived so as to solve the problems of the prior art described above.

One of the objects of this invention is to provide an apparatus that produces a mold of large size with further higher quality simply and rapidly.

Another object of the invention is to provide a method for producing a mold, in particular using the apparatus described above.

Brief Description of the Drawings

FIG. 1 is a sectional view showing an apparatus for making molds which is produced according to one embodiment of this invention.

FIGS. 2 and 3 respectively are enlarged views of a major portion of FIG. 1 so as to explain a method of producing a mold according to one embodiment of this invention.

FIGS. 4a to 4c show die steel of a cylindrical bar in which various slits are formed according to one embodiment of the invention.

FIGS. 5a to 5b respectively are views showing processes for manufacturing molding flasks described in FIGS. 1 to 3.

FIGS. 6a and 6b are views showing molding flasks in the

prior art.

FIGS. 7a and 7b respectively show molding flasks according to one embodiment of the invention.

Best Mode for Carrying Out the Invention

According to this invention described above, an apparatus for producing molds includes **a die set** having a reception portion for die steel to be used as a mold; **a mold flask** having a shape corresponding to a shape of the mold, the mold flask being detachably installed and being sealing an open upper side of the reception portion of the die set; **a heating means** for heating die steel such that die steel charged in the reception portion of the die set is transferred into a semisolid state where a liquid phase and a solid phase are mixed; **a pressurization plunger** for pushing the semisolid die steel in the upper direction such that the mold flask is filled with die steel heated to the semisolid state by the heating means, the pressurization plunger being installed movably upwards and downwards through an opening in the reception portion of the die set ; **a pressure control means** for improve a filling efficiency of die steel by making a circumference of the mold flask in vacuum when the pressurization plunger pressurizes die steel ; and **a graphite heat insulating plate** for insulating the upper portion of die steel being heated by being placed at the upper portion of die steel at the time of heating and for moving so as to be away from a progress direction of the semisolid state die steel, the graphite heat insulating plate being installed between die steel

charged in the reception portion and the mold flask such that left/right movement is possible. Herein, the heating means includes an induction heating coil for heating die steel charged in the reception portion of the die set, which is installed on the circumference of the reception portion thereof; and a control portion for controlling a heating temperature and an operation of the induction heating coil. The induction heating coil is installed such that it may be replaced by a high frequency or a medium frequency coil according to the size of die steel charged in the reception portion thereof.

The mold flask includes a cooling pipe arrangement selected from the group consisting of a cooling pipeline, a salt pipeline, and a Zn alloyed Zamak pipeline which generally match a contour line of a shape of a mold to be formed within a structure of a mold flask.

Die steel is a cylindrical bar having a plurality of slits on a circumferential curved surface along a longitudinal direction. The plurality of slits are symmetrical with each other in respect to an axis of the cylindrical bar.

A method of producing a mold using a molding machine according to this invention comprises the steps of:

(a) charging die steel including inserting die steel in a reception portion of a die set and then placing a graphite insulating plate above die steel charged in the reception portion thereof;

(b) installing a mold flask such that an upper region of the reception portion thereof is sealed;

(c) heating metals such that solid metals charged in a reception portion thereof are transferred to a semisolid state in which a solid phase is mixed with a liquid phase;

(d) filling the semisolid metals in the mold flask under pressure after separating the insulating plate from a progressive direction of the semisolid die steel; and

(e) cooling the filled die steel in the mold flask.

Herein, cooling in the cooling step includes separately cooling with the mold flask being separated from the die set, and can be a repeating process that starts again when a new mold producing process using new die steel and a new mold flask is completed.

Heating in the step (c) is performed by an induction heating furnace. When die steel is of a cylindrical bar and is less than 150 PHI in diameter, high frequency indirect induction heating is used. When die steel is of a cylindrical bar and is more than 100 PHI, medium frequency direct induction heating. In this case, die steel has a plurality of slits on a circumferential curved surface along a longitudinal direction. The plurality of slits are symmetrical with each other in respect to an axis of the cylindrical bar.

Heating in the step (c) is performed at a temperature

of 1200 ℃ to 1540 ℃ for between 1 and 120 minutes.

In the step (d), the ratio of the liquid phase in the semisolid die steel is 0.01 to 0.9, an applied pressure is 3 to 500 Mpa and a pressurization rate is 0.1 to 10 m/s.

Heating step, filling step, and cooling step all are performed under at least one atmosphere selected from the group consisting of vacuum, argon, nitrogen, and hydrogen atmospheres.

Cooling step (e) is performed at the cooling rate of 40 ℃/s.

After the cooling step, an annealing treatment or a quenching and annealing treatment can be further added.

A mold flask may be a ceramic mold flask made through steps of forming a master pattern and then producing a mold flask in ceramic slurry so as to match the master pattern. In this case, a step for producing a silicon mold is inserted between a step for forming a master pattern and a step for producing a mold flask, thereby making a mass production of a mold possible.

In addition, a method for producing a mold according to this invention includes forming a lot of slits in die steel; heating die steel having the slits so as to make the die steel in a semisolid state where a solid phase and a liquid phase are mixed; filling the die steel in the

semisolid state into a mold flask under an increased pressure; and cooling the die steel filled in a mold flask.

Hereinafter, a preferable embodiment of this invention will be explained with reference to accompanying drawings.

FIG. 1 is a sectional view generally showing a molding machine according to one embodiment of this invention.

As shown in the drawing, a molding machine according to one embodiment of this invention includes a die set 10, a mold flask 20, a heating means, a thermal insulating means 70, a pressurization plunger 41 and a pressure control means.

Die set 10 is, for example, a graphite die set, and is fixed on a lower face of a fixing plate 61.

Die set 10 includes a sleeve 12 of graphite or aluminum material that forms a reception portion 11 thereof with an upper region of the reception portion being open, a thermal insulating material 13 and a ferrite based protection film 14. The thermal insulating material 13 and ferrite based protection film 14 encloses an outer face of the sleeve 12(Please refer to FIG.2). The portion of the fixing plate 61 that matches the upper region of the reception portion 11 has a through hole 57, which forms a part of the reception portion 11. The reception portion 11 is charged with die steel which is to be manufactured into a mold.

On the upper face of the fixing plate 61 is installed

a mold flask 20 of ceramic material or graphite material. The mold flask 20 seals an open upper region of the reception portion 11 and is detachably installed. The mold flask 20 has a filling portion 21 taking a shape of a mold and the filling portion 21 is formed such that it faces the reception portion 11 of the die set 10. Such a mold flask 20 is manufactured from a master pattern or a mock-up having the same size or shape as a mold to be produced.

Heating means has an induction heating coil 31 installed to enclose the sleeve 12 of the die set 10, and a control means (not shown) for controlling an operation and a heating temperature of the coil 31. Preferably, the coil 31 is replaceably installed, together with a ferrite prevention film 14. If the coil 31 is installed replaceably, it is possible to install any one of a high frequency, medium frequency, and low frequency induction heating coils depending on the size of die steel 80 which is charged in the reception portion 11.

A top end of the pressurization plunger 41 is placed in the inside of the reception portion 11 such that the pressurization plunger 41 seals a lower region of the reception portion 11. The pressurization plunger 41 is moved upwardly and downwardly by a cylinder 42.

The heating insulating means 70 has a graphite heating insulating board 71 and the graphite heating insulating board 71 is installed between the die steel 80 charged in the reception portion 11 and the mold flask 20 such that

the graphite heating insulating board can make a left/right movement by the cylinder 72. Accordingly, during heating the graphite heat insulating board 71 is placed above die steel charged during heating, thereby insulating a heat of the upper portion of the die steel being heated. At the time of filling, the graphite heat insulating board 71 is left away from the progress direction in which die steel heated to semisolid state progresses. The graphite heat insulating board 71 is preferably spaced out 1 to 10 cm from the die steel charged. In addition, The thickness of the graphite heat insulating board 71 is preferably 1 to 20 cm. Because the graphite heat insulating board is placed above die steel being heated in this way, the dissipation of heat due to radiation and convection of heat is prevented and heat generation of graphite makes the temperature of the upper portion of die steel higher. In addition, According to the size of die steel the temperature of an upper region of die steel can be controlled by controlling the thickness of the graphite heat insulating board and the space between the graphite heat insulating board and die steel.

A pressure control means includes a vacuum chamber 51 having therein a mold flask 20, a fixing plate 61, a die set 10, and a pressurization plunger 41; sealing plates 52 and 53 sealing the vacuum chamber 51 at the lower side and the upper side thereof; and a vacuum pump 54.

The upper sealing plate 53 is moved by an elevating cylinder 62 which is installed at an upper portion of a

mold fabrication apparatus. At lower end of the elevating cylinder 62 is installed a grip portion 63 for gripping the mold flask 20 and then putting the mold flask 20 on the fixing plate 61 or separating the mold flask 20 from the fixing plate 61.

In addition, as shown in FIGS. 7a and 7b, the mold flask 20 has at the inside thereof a cooling pipe arrangement 22 generally formed along a contour 23 of a shape of a mold to be generally formed such that a shape of the cooling pipe arrangement 22 is generally similar to that of the contour 23. The cooling pipe arrangement 22 can be selected from the group consisting of a cooling pipeline, a salt pipeline and a Zn alloyed Zamak pipeline.

The prior art mold flask 20 shown in FIGS. 6a and 6b has a linear type cooling line 202, independently of a contour 203 which follows the shape of the mold to be formed. However, the mold flask 20 according to this invention, as shown in FIGS. 7a and 7b, has a cooling pipe arrangement 22 generally formed along a contour 23 of the shape of the mold to be formed such that a shape of the cooling pipe arrangement is generally similar to that of the contour. Therefore, in the manufacture of a modern mold having a lot of curved surfaces, the more efficient homogenous cooling may be accomplished.

The method of fabricating a mold using a mold fabrication apparatus according to one embodiment of this invention will be explained.

Firstly, with reference to FIGS. 5a and 5b, a step of manufacturing a mold flask 20 from a master pattern will be explained.

In the case of a ceramic mold flask, as shown in FIG. 5a, first, a master pattern 1 or a mock-up is formed using a rapid prototype apparatus or a CNC apparatus. At this time, the master pattern or the mock-up should be machined, considering a shrinkage/expansion rate according to the thermal effect during the following processes. Thereafter, the master pattern 1 is placed inside of a frame (not shown) such as a mold box and then ceramic of slurry form is poured into the inside of the frame to solidify it. Accordingly, a mold flask 20 of ceramic material having a shape inverted with a shape of the master pattern 1 is formed. In the case of a graphite mold flask, the graphite mold flask is directly machined by a CNC apparatus.

In addition, with the reference to FIG. 5b, a master pattern 1′ has both faces, the both faces corresponding to a negative image of the shape of an object, unlike in the case of FIG. 5a and the master pattern 1′ forms lots of silicon rubber molds 2 by using a mold flask. Next, lots of mold flasks 2′ are formed by using respective silicon rubber molds 2. In FIG. 5b, since the silicon rubber molds 2 are mass-produced in a simple way, it is preferable when the same shaped molds have to be produced in a multitude.

With reference to FIGS 4a to 4c, the step of preparing

die steel 80 and forming a lot of slits on the circumference of die steel 80 will be explained.

For example, die steel 80 is preferably bar steel; die steel 80 is more preferably bar steel having a diameter of 40 mm and more than 40 mm. Die steel 80 is fabricated by a gravity casting or continuous process and then a rolling or forging process. In addition, the process of fabricating bar steel may include a stress relief treatment and a solution heating treatment. In addition, the above mentioned all processes can be performed continuously. In this case, it is preferable that the cylindrical bar has the grain size of the microstructure of 0.5 μm to 300 μm. The cylindrical bar is cut into such a degree of a size that it may be formed into a mold, and a lot of slits 81 are formed on the circumferential curved face of the cylindrical bar. A proper number of slits 81 are formed depending on the diameter of the cylindrical bar being used. The slits 81 may be formed by cutting the curved face of the cylindrical bar by a saw. The slits 81 are, preferably, formed along an axial direction and generally formed in a symmetrical structure in respect to an axis line A-A'. A depth of slits 81 may be controlled within 1 to 10 cm depending on the size of a cylindrical bar. By forming a lot of slits on the cylindrical bar, an induction current may be flowed to a central portion of die steel in the following induction heating step. Accordingly, since the central portion of die steel is heated almost simultaneously with a surface portion of die steel, the temperature difference between the central portion and the surface

portion of die steel may be miniaturized.

Next, a step of fabricating a mold using an apparatus according to this invention will be explained with reference to FIGS. 1 to 3.

Die steel 80 to be fabricated into a mold is charged into the reception portion 11 of the die set 10. Charging step includes inserting die steel 80 into the reception portion 11 of die set 10 and disposing a graphite heat insulating board 71 above die steel 80. In inserting die steel, die steel 80 is first placed on an upper face of the pressurization plunger 41 and then the pressurization plunger 41 moves such that die steel disposes at a center of the reception portion 11 of the die set 10 when die steel is disposed or after die steel is disposed.

After die steel is received into the reception portion 11 of die steel 80, the graphite heat insulating board 71 is placed above die steel. The heat insulating board 71 as mentioned above is a graphite board. Next, under the state that a mold flask 20 is gripped by a gripping means 63, the mold flask 20 is attached to the upper face of the fixing plate 61 by downward movement of a cylinder 62. The mold flask 20 attached is downwardly supported by a rod of a cylinder 62 having the gripping means 63. Next, by operating a vacuum pump 54 of a pressure control means, an air within a chamber including an inside of the reception portion 11 is all removed and thereby the chamber becomes vacuous.

After the inside of the reception portion 11 becomes vacuous, die steel 80 is heated such that die steel received within the reception portion 11 is in a semisolid state where a solid phase and a liquid phase are mixed. In this case, since the inside of the reception portion 11 is in a vacuum state, the phenomenon that die steel 80 is oxidized during heating does not occur. The chamber including the reception portion may be in the atmosphere of a gas such as argon, nitrogen or hydrogen, etc., instead of in the atmosphere of vacuum.

The applicable heating type includes direct or indirect induction heating type of high frequency, medium frequency, or low frequency. At this time, so as to heat die steel homogenously independently of the size of die steel 80, a high frequency indirect induction heating method is used when the diameter of die steel 80 is approximately 150 ㎜ and less than 150 ㎜, and a medium frequency direct induction heating method is used when the diameter of die steel 80 is 100 ㎜ and more than 100 ㎜. Preferably, when the diameter of die steel 80 is less than 150 ㎜, a high frequency indirect induction heating method is used and a sleeve 12 is formed of graphite material. More preferably, when the diameter of die steel is about 100 ㎜, a medium frequency direct induction heating method is used and the sleeve 12 is formed of alumina material. Most preferably, a lot of slits 81 are formed on die steel 80.

Induction heating is to form a strong magnetic field

round die steel to be heated and to heat die steel by an induction current on die steel induced by the magnetic filed. Induction current flows along the surface of die steel and thus the surface of die steel is heat-generated.

As die steel according to this invention, as shown in FIG. 4a to 4c, has a lot of slits 81, induction current flows along the slits 81 to the center of die steel. Accordingly, unlike prior art where only the surface of die steel is heat-generated and thus a big temperature difference between the surface and the center thereof is generated, die steel having a lot of slits according to this invention, the temperature difference between them becomes little and die steel reaches a homogeneous semisolid state more rapidly. In addition, in a method of fabricating a mold according to this invention a temperature control of an upper portion of die steel is important since the upper portion of die steel is a part which directly contacts the mold flask first and thus the upper portion of die steel is the most great element which controls the quality of a molded product at the time of molding. Accordingly, by placing a heat insulating board formed of graphite having higher exothermic amount than metal on the upper portion of die steel and thus blocks heat which vanishes due to radiation or convection etc. and the temperature of an upper portion of die steel becomes further higher due to heat-generation of graphite.

As described above, heating of die steel makes die steel in a semisolid state where a solid phase and a liquid phase

is mixed. At this time, a heating rate and a temperature holding time are controlled by a heating pattern already set in a control portion so that die steel 80 in a semisolid state has a homogenous microstructure. Preferably a temperature range is from 1200 to 1540 ℃ and a temperature holding time ranges from 1 to 120 minutes.

In the course of a heating step, when a liquid phase ratio of die steel reaches about 0.01 to 0.9, preferably 0.05 to 0.4, the heat insulating board 71 is moved away from the progressive direction of semisolid die steel and then the filling portion of the mold flask is filled under pressure by semisolid die steel 80 by moving a pressurization plunger 41 forward.

Number 80' shown in FIG. 3 indicates filled semisolid die steel. Here, a forward moving rate of the plunger 41 is 0.1 to 10 m/s, and an applied pressure is 3 to 500 Mpa. In addition, at the time of filling, in the case of a ceramic mold flask a filling temperature is 25 to 500 ℃, and in the case of a graphite mold flask, a filling temperature is 100 to 700 ℃.

Lastly, by cooling die steel 80 which fills a filling portion 21 of the mold flask 20, a mold with a desired shape is obtained. It is preferable that cooling is performed at a cooling rate less than about 40 ℃/s.

After the cooling step, an annealing treatment or a quenching and annealing treatment may be performed. It is

preferable that the annealing treatment is performed at 450 to 650℃ for 1 to 180 minutes and the quenching treatment is performed at 800 to 950 ℃ for 1 to 30 minutes.

Provided, in the case that a mold of the same shape will be manufactured in a large number, a large number of mold flasks 20 are manufactured using a method as shown in FIG. 5b. Next, after the filling portion 21 of the mold flask 20 is filled by the semisolid die steel 80, the cylinder 62 is escalated and the mold flask 20 is separated from the gripping portion 63 and the mold flask 20 is then cooled separately. Then by charging new die steel 80 into the reception portion 11, gripping a new mold flask 20 by a gripping means 63 and then attaching the mold flask 20 on the fixing plate 61, a mold can be manufactured continuously and rapidly.

Industrial Applicability

According to this invention, in place of powdered metal, die steel, in particular by applying a semisolid rapid tooling method, supply and demand of raw material is easy and its cost is cheap. Also, since die steel is used, a size of graphite die set is small than in the case that powdered metal is used and thus an apparatus can be miniaturized. In addition, a mold flask is installed at the outside of the graphite die set and thus the replacement of a mold flask can be rapid and easy. In addition, since the semisolid metal is pressurized from only either one of both sides, the control of the applied pressure is easy. Since a lot of slits are formed on die steel, even though

die steel is large, homogeneous semisolid die steel is more rapidly and more repeatedly made. Accordingly, even a large size of mold can be cheap produced. In addition, by forming homogeneous cooling line consistent with a shape of a mold in a mold flask, in a modern process for forming a mold having a lot of curved faces, more efficient homogeneous cooling can be realized.

The embodiments described above are exemplary only, and the scope of the invention is not limited to them. As will be clear to one skilled in the art, any variations can be made to them without departing from the attached claims.